The Office of Naval Research and the Naval Research Laboratory Experimentation in Underwater Acoustic Communications Research

U.S. Navy and Air Force Reservists integrated seamlessly in at-sea experiments in the past year on board NRL research vessels

By U.S. Navy Reserve Cmdr. Michael T. McCord

Underwater digital acoustic communications (Acomms) with added networking capability is one of the leading research programs at the Naval Research Laboratory (NRL) — one that supports advances in the Sea Basing concept of the Navy's Sea Power 21 initiative. Radio frequency and laser communications have limited ocean range, but Acomms provide strategic communications at ranges up to 20 nautical miles.

The goal is to improve the technologies, used by the Office of Naval Research (ONR) and the Space and Naval Warfare Systems Command (SPAWAR), to enhance communications with submarines and between autonomous undersea vehicles. Improvements are delivered to the fleet in a series of milestones. ONR raises the bar each year for increased Acomms data rates, and we are in a continuous process of pushing technology advancements to meet these goals.

To this end, the NRL civilian staff teamed with members of the Navy and Air Force Reserves to take Acomms research to the ocean. Advances directly support future Navy capabilities for communications and networking between submarines, autonomous undersea vehicles, surface ships and test ranges. Applications for Acomms technology include rapidly deployable systems, minehunting and mine countermeasure systems, tactical communications, advanced weapon systems and undersea networking.

Technical Description

NRL's research concentrates on understanding the underwater medium and developing techniques that improve the communications efficiency under less-than-optimal channel conditions.

Low signal-to-noise ratio, multipath, reverberation and motion-induced Doppler frequency shift are examples of adverse channel conditions that limit data rates and lead to higher bit-error rates. The Acomms team tests new modulation techniques and evaluates the ability of new algorithms to improve communication rates.

The team also characterizes the ocean's acoustic channels so the theoretical maximum communication rate can be determined under varying conditions. For one-to-one acoustic data telemetry, focus is on achieving the highest data rate using phase-coherent acoustic communication techniques over a given bandwidth and a given set of acoustic channel conditions. For networking, focus is on the robustness of acoustic handshaking and maximizing channel capacity for multiple users.

Highly specialized equipment is used to conduct at-sea experiments. In a typical deployment, two subsurface systems are placed in the water column and moored about 30 meters below the surface. A third system, modified for towing behind the vessel, simulates an autonomous undersea vehicle for researching communications between submerged vessels.

The two moored systems are loosely tethered to surface buoys that provide radio frequency communications with the research vessel over a wireless local area network (LAN). To simulate an autonomous undersea vehicle, NRL developed a hydrodynamic frame for the Acoustic Communications Data Storage system. Controlled from the ship's lab, the two moored systems and the towed system conduct digital networking using underwater acoustic communications.

Space-efficient PC104 computers provide the brains and interface with acoustic projectors for transmitting and hydrophones for receiving. A typical experiment is conducted in three days and ends when the batteries are exhausted or the on-board 300 GB data storage drives are full.

Communications between the moored Acoustic Communications Data Storage

Program leader, Dr. Tsih C. Yang (right), a world-class expert in acoustic communications research, briefs the team in the Research Vessel Endeavor laboratory. Dr. Yang gave the reservist team an overview of the science mission, goals and anticipated results.

U.S. Air Force Maj. Richard Friedman and Navy Reserve Cmdr. Dan DiDomenico set up the wireless local area network equipment inside the Acoustic Communications Data Storage Subsurface Unit.

The team deploys the Acoustic Communications Data Storage Subsurface Unit. The operations area was about 70 nautical miles east of Delaware, located near the edge of the continental shelf. Operations areas are selected in the more challenging acoustic regions to better understand the effects of multipath, reverberation and Doppler.

buoy systems and a NRL-chartered research vessel require temporary installation of a 2.4 GHz antenna. With special Federal Communications Commission (FCC) authorization, the wireless LAN operates with 6 watts of power, providing communications out to 8 nautical miles.

The NRL Civilian Team

Dr. Tsih C. Yang leads one of the high-visibility research programs at NRL. He is a world-class expert in acoustic communications research. The team also includes signal-processing experts, Paul Gendron, Wen-Bin Yang and Jeff Schindall, with engineering services provided by Michael McCord.

Research results have appeared in more than 20 publications. Two patents have been granted with two more in process. The team has participated in eight at-sea experiments in various parts of the world under different sound propagation conditions.

Naval Reservists integrated seamlessly in several at-sea experiments in the past year on board NRL research vessels. Michael McCord, an NRL engineer (and Naval Reservist) coordinates the use of reservists in these experiments. Reservists are usually service members attached to units supporting the ONR or Naval Sea Systems Command. During the experiments, there were many long days, little time off and intense pressure to meet the schedule.

The weather was poor at times, creating challenges in port and at sea, but reservists stepped up to each task often suggesting improved ways of using the equipment, and always setting the highest example for their respective services. It was evident early on that they were making significant contributions to the program.

Naval Reserve Chief Fire Control Technician Jan Caban was eager to participate in the NRL experiment. *"I saw the opportunity as tremendously exciting — a chance to go to sea again, which I truly love …"*

Naval Reserve Cryptologic Technician (maintenance) 1st Class Catherine Christian said the experience exceeded her expectations. *"… The team atmosphere of the NRL research staff particularly impressed me. The other reservists onboard and the vessel's crew all became equally enthusiastic about the goals of the project. I'm sure it was this out-of-the-box approach that led the entire team to overcome multiple technical and weather challenges…"*

The Excitement Begins

Typical at-sea experiments begin with a week of system preparations. University of Delaware-owned Research Vessel Cape Henlopen at 120-feet and 197 gross tonnage was not the usual ride for Navy officers and Sailors. The ride was rough because the Henlopen is a small vessel. But the mission was important, and it wasn't long before reservists got their "sea legs."

Equipment was installed in racks to facilitate system integration months before the experiment. This provided excellent protection for shipment and allowed quick set-up on board. Almost all the equipment used was purchased off-the-shelf and has proven to be dependable.

The Surface Acoustic Communications Data Storage unit contains the wireless LAN electronics and is loosely tethered to the subsurface unit. Fiber optic lines within the tether provide a 100Base-T network link to the subsurface unit.

Located near the edge of the continental shelf, operations areas are selected in the more challenging acoustic regions to better understand the effects of multipath, reverberation and Doppler. Among the challenges our team faced in the September 2003 experiment was rough weather in the Atlantic Ocean caused by the approach of Hurricane Isabel.

Conditions were so choppy that by the time we arrived on station, we had quite a challenge to deploy the Acoustic Communications Data Storage units. The difficulty was in standing still while the ship was rocking and having our hands free to conduct the experiment.

Results

During this experiment, data from point to point transmissions were evaluated for high data rate (voice and video rate) acoustic telemetry. Data between moored and towed systems were evaluated for acoustic communication networking. Some analysis was conducted at sea, but the bulk of the work is done in the lab. NRL has developed system performance modeling and prediction capability that incorporates site-dependent signal propagation characteristics.

CTM1 Catherine Christian performs an Acoustic Communications Data Storage pressure vessel air evacuation.

Getting sensitive electronic systems into the water can be tricky from the deck of a rolling and pitching vessel. Lt. Derek Buzasi and Ensign Kim Pavlovic setting up the Acoustic Communications Data Storage towframe.

Improved algorithms have been developed to mitigate environmental and platform motion effects on communications data rate and bit-error rate. Applications include reliable communications for submarines operating at tactical speeds and depths and robust networking capabilities between unmanned underwater vehicles.

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Michael McCord is an engineer in the Naval Research Laboratory, Code 7120 and a commander in the U.S. Naval Reserve.